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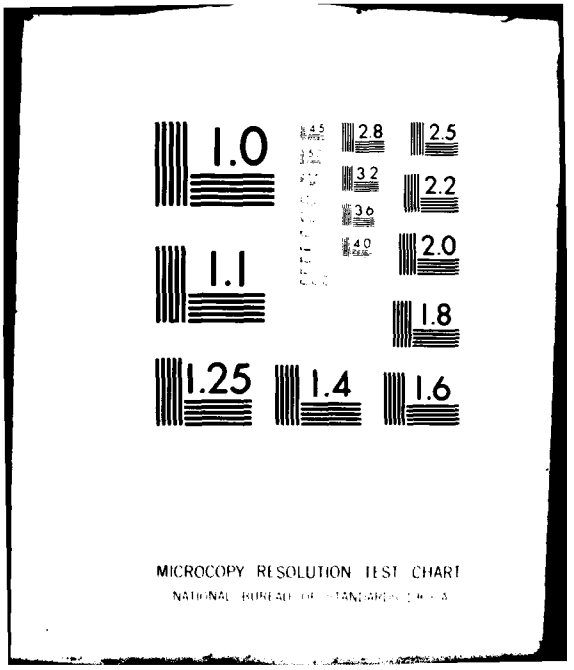
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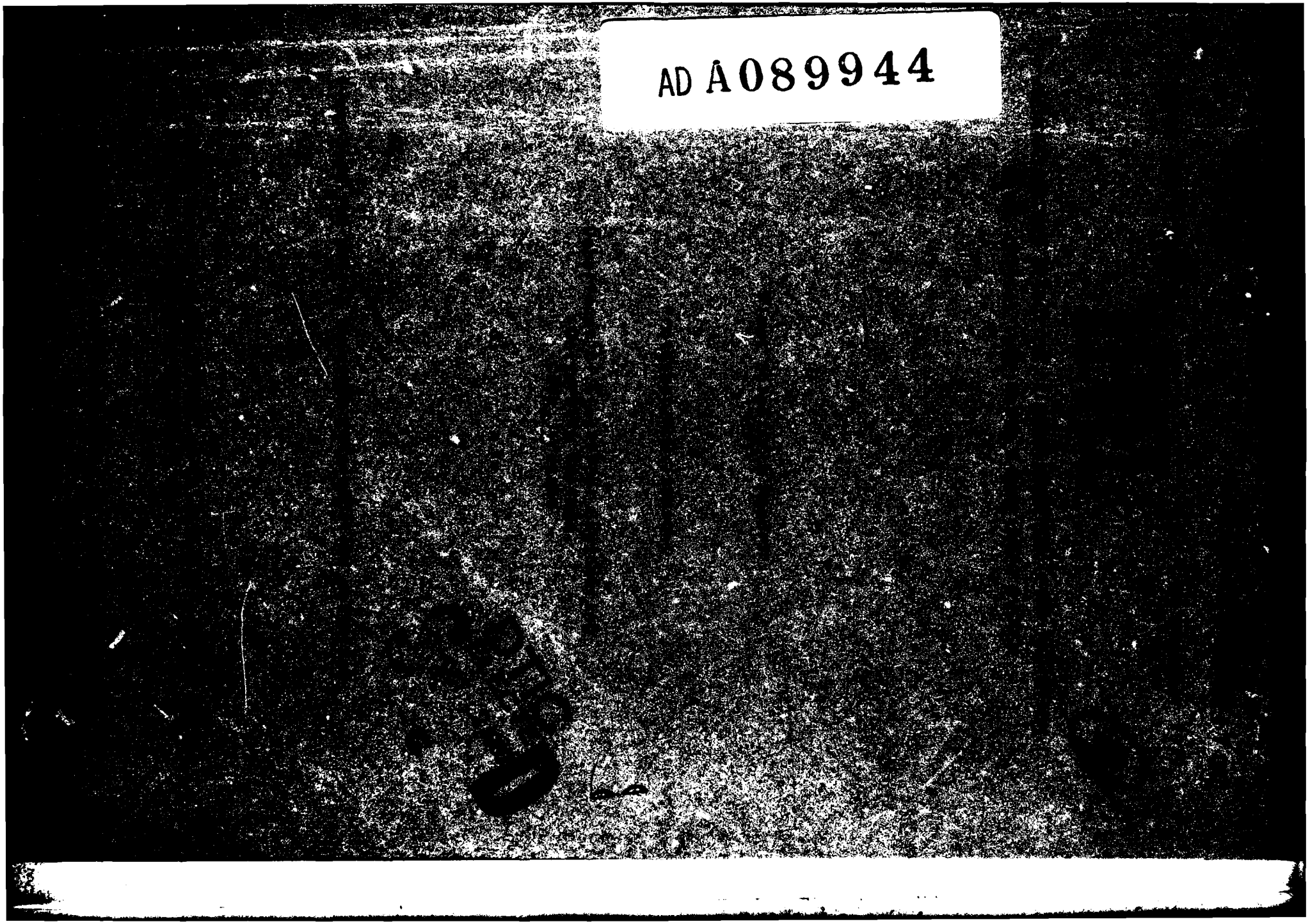

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(6) GENERATION AND DETECTION OF SUBMILLIMETRE (FIR) RADIATION USING OPTICAL PUMPING IN A GAS LASER SYSTEM.

(9) Final Scientific Report.

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(19) TR-

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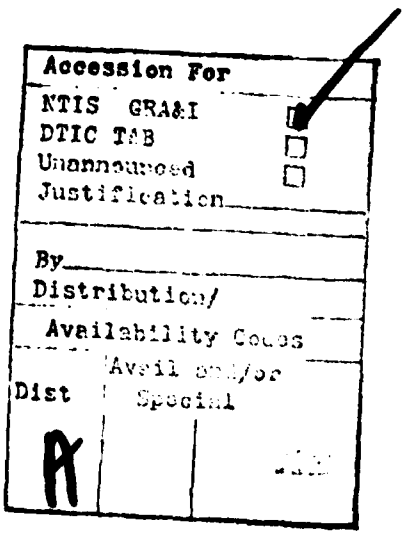

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20. Abstract

The development of a CO_2 waveguide laser as a pump source for a CW far-infrared D_2O laser is described. Performance with regard to output power and tunability is reported with special reference to the application of these lasers in over-coming the mismatch which can exist between the pump laser frequency and the vibrational absorption of the pumped molecule. This report presents summaries of the construction and performance of such lasers as well as photoconductive detectors and points the direction towards the achievement of a tunable source of pump radiation for a D_2O laser. Absorption measurements in D_2O using the waveguide laser are also presented.

Lasing action is straight H_2O and D_2O lasers is also summarised over the 20 - 120 micron wavelength range.

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INTRODUCTION

During the period covered by the Grant under review two distinct and separate items of research were carried out:-

(i) Development and completion of work associated with far infrared lasing action in water and heavy water vapour over the wavelength range 20 - 120 microns.

(ii) Design and fabrication of a boron nitride waveguide laser operating continuously in the 9 - 10 micron wavelength range using CO_2 transitions, together with the development of an optically pumped heavy water system.

H_2O AND D_2O LASER SYSTEMS

Far Infrared Laser Action in Water and Heavy Water Vapour

A comprehensive series of tests on pulsed laser action in H_2O and D_2O vapours using a 1.7 m laser incorporating several unique resonator features was carried out. Laser power output was measured as a function of vapour pressure, excitation current and pulse repetition frequency at wavelengths of 28 μm in H_2O and at 36 μm in D_2O. The round trip gain of the H_2O laser was found to be in the order of 15% and an increase in output power of up to 50% was obtained by the addition of helium.

Full design procedures and the detailed results are available in the following reports available as Masters' Theses:

1) G. McCann: "Design and Development of a Far Infrared Laser System". M.Eng.Sc. Thesis, University College, Cork 1977.

2) C.K. Kelleher: "An Investigation of the Far Infrared Lasing Characteristics of H_2O and D_2O."
M.Eng.Sc. Thesis, University College, Cork 1977.

3) P.A. Canty-Collins: "An Analysis of a Water Vapour Laser in the Far Infrared".
M.Eng.Sc. Thesis, University College, Cork 1979.

GENERATION AND DETECTION OF SUBMILLIMETRE (FIR) RADIATION USING OPTICAL PUMPING IN A GAS LASER SYSTEM

An optically-pumped continuous D_2O laser capable of generating enough power at 385, 114 and 66 microns would lead to an extremely sensitive heterodyne receiver if the above wavelengths could be used as local oscillator sources. For example, communications in the far-infrared would benefit and, in particular, the diagnostic methods used in fusion research plasmas would be greatly improved. It is not trivial, however, to realize such a laser owing to the mismatches that occur between the emission lines in CO_2 and the absorptions in D_2O, amounting to 0.32 GHz, 0.68 GHz and 1.5 GHz for R(22), R(12) and P(32) respectively.[1]

No problem exists, of course, with a CO_2 TEA pump laser which can have an output several GHz wide due to pressure broadening, but for CW operation recourse must be made to capillary waveguide lasers which (unlike conventional devices) can operate at 100's of torr with consequent gain profiles typically 100's of MHz wide[2].

Waveguide lasers have been constructed in this laboratory from boron nitride (BN)[3]. The combination of high thermal conductivity, low coefficient of expansion and ease of machining makes BN an ideal material with a better surface smoothness than that obtainable from beryllium oxide (BeO) or alumina (Al_2O_3). A typical laser consists of a 1.7 x 1.7 mm channel with 24 cm discharge length. Running voltages are minimised by four electrode geometry, pressure gradients are reduced by introducing gas at the centre and cooling is effected with a water cooled copper block.

A maximum output power of 7.6 W was attained at ~125 torr. Replacement of one of the cavity mirrors with a 150 lines/mm grating yielded frequency tuning over the 9.6 and 10.6 μm bands. In particular, output powers up to 3 W have been measured on individual lines.

A tuning range of 200 MHz line centre has already been achieved by mounting the output mirror on a piezoelectric translator. Higher tuning ranges are in theory possible but a limitation is imposed by the present cavity length. However, the laser's capability has been confirmed by absorption in D_2O on the R(22), R(12) and P(32) lines in the 9.6 μm band over the 200 MHz range for several values of D_2O pressure. In addition, extension of the bandwidth to ~1 GHz by means of Cadmium Telluride (CdTe) etalon is planned as the final step for successful lasing.

N.B.: Full design, fabrication details and results have already been presented to AFOSR in the form of a Technical Report dated 1 June 1979 (10 pages, 6 figures).

References

1. S.J. Petuchowski, A.T. Rosenberger and T.A. De Temple, IEEE, J.Q.E., QE-13, 476 (1977).

2. J.J. Degnan, J. Appl. Phys., 45, 257 (1974).

3. A. Papayoanou, IEEE, J.Q.E., QE-13, 27 (1977).

Publications arising from the above work

1. DE Evans*, SL Prunty and MC Sexton;
"Towards an Optically Pumped Continuous D_2O Laser"
4th Europhysics Sectional Conference on Atomic and Molecular Physics of Ionised Gases, Essen, Germany, September 1978, p. 59.

2. DE Evans*, SL Prunty and MC Sexton;
"A Boron Nitride Capillary Carbon Dioxide Waveguide Laser for Optically Pumping Heavy Water"
Second International Conference on Infrared Physics, Zurich, Switzerland, March 1979, p. 188

3. SL Prunty, DE Evans* and MC Sexton;
"Development of an Optically Pumped CW D_2O Laser for Plasma Diagnostics"
IEEE International Conference on Plasma Science, Montreal, Canada, June 1979, p. 97.

The most recent paper is:

4. DE Evans*, SL Prunty and MC Sexton;
"A Boron Nitride CW Carbon Dioxide Waveguide Laser for Optically Pumping Heavy Water". Infrared Physics, 20, 21, 1980.

Abstract

Boron nitride has been used to fabricate a 1 cm^3 CW CO_2 capillary waveguide laser which operates at 130 torr gas pressure, and generates 7 W of 10 μm radiation untuned and up to 3 W on individual grating-selected emission lines. Pressure broadened gain profiles are limited to ± 200 MHz from line centre by longitudinal cavity mode spacing. Increased absorption of the 9 μm band R(22) line by D_2O vapour is observed as this line is tuned across the broadened gain profile towards its D_2O absorption.

In addition, and also in direct collaboration with the Culham Laboratory, the following paper on photoconductive detection of FIR superradiant D_2O lasing action was published:

5. DE Evans*, RA Guinee, DA Huckridge*, G Taylor*;
"Times resolved Pulses and Wavelength Measurements for the 114 and 66 micron emissions in the FIR Superradiant D_2O Laser". Optics Communications, 22, 337.

Abstract

A 1 ns risetime gallium-doped germanium detector operating

at 4.2 K was used to record time-resolved FIR pulses at wavelengths between 114 μm and 50 μm D_2O vapour pumped by the 9.6 μm band CO_2 TEA laser transitions at R(12) and P(32). Average powers of 6 MW and 11 MW respectively were measured. Fabry-Perot spectroscopy identified the dominant FIR output pumped by R(12) as 112 ± 3 μm, while P(32) pumping gave 66 ± 2 μm, 117 ± 2 μm and 50.0 ± 0.5 μm in the approximate ration 100:10:1 at the laser window.

* UKAEA Culham Laboratory, Abingdon, Oxon, UK.

SUMMARY AND FUTURE TRENDS

The fact that a small number of the known FIR lines operate in the CW mode with relatively low pump powers would seem to indicate that the degree of overlap between the absorbing FIR lines and CO_2 pump lines is poor. The degree of overlap can be improved by using waveguide CO_2 lasers in which a tunability of over 1 GHz has been demonstrated and tuning ranges in excess of 2 GHz have been predicted. However, these lasers have output powers considerably smaller than those required for optical pumping; methods must therefore be sought which will improve the output power while still maintaining the tunability. An obvious method is to increase the gain length of the laser but unfortunately this places a limitation on the maximum tuning range to one half the longitudinal mode spacing on either side of line center. This problem can be overcome, in theory, by the use of an internal etalon within the laser cavity for longitudinal mode selection, however, this requires sophisticated tuning techniques as well as stringent long term frequency stability requirements. We propose to overcome these problems by using a new type of waveguide laser. Progress has already begun on the construction of this new laser which involves having a series of capillary tubes in a collinear configuration. This arrangement should allow one to maintain the tunability of a short waveguide laser while at the same time having the output power of a longer laser. This will be reported in due course.